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SELF-LUMINOUS NIGHT HAZE.

By E. E. BARNARD.

(Read April 25, 1919.)

In the *Proceedings of the American Philosophical Society*, Vol. 50 (1911), p. 246, a paper was contributed by the present writer on the subject of "Self-Luminous Night Haze," where observations were given of a kind of luminous, streaky haze seen at night in 1910 and 1911 which seemed to have no connection with the ordinary aurora. Apparently this is a little-known phenomenon. It is well worthy, however, of record and study. The only reference to it that I have found, and it was not known to me at the time of my previous paper, is an account of what was probably the same phenomenon by T. W. Backhouse, who gives occasional records of it in a long paper on the aurora, under the name of "irregular auroras," as far back as December 13, 1862. I will quote his entire reference to the phenomena as given in No. II, p. 109, *Publications of West Hendon House Observatory*, Sunderland, England. "'irr.' means a night when the aurora was only an irregular one, not perceptibly of a magnetic character; I do not know whether these are true auroras or not. They consist of bands and patches of light, the positions and direction of which have no particular relation to either the magnetic declination or dip; they appear to lie in a horizontal stratum, but differ from clouds in being self-luminous and transparent, and also not exactly like any kind of cloud in appearance, and I should think they are at a greater height. They do not appear specially in the north. As auroras of this class are always faint, their spectrum proves little; but I have never made out that it was more than a continuous one. An examination of this table, however, shows that these irregular auroras are more frequent about the time of the maximum of sun-spots than at the minimum, which goes towards proving that they are of the same magnetic nature as the ordinary auroras." Mr. Backhouse did not seem to notice that

this luminous matter is perhaps only ordinary thin haze which, from an unknown cause, is sometimes luminous at night. I believe this same haze is also present in the daytime.

In my previous paper to the Society attention was called to the fact that the objects observed by me did not seem to have any connection with the luminous night clouds of O. Jesse of twenty-five or thirty years previous. His objects were at very great altitudes, some fifty-two miles above the earth's surface, and were visible by direct sunlight which shone on them long after it had ceased to illuminate the ordinary clouds. They were therefore not self-luminous. They were only seen at the times of the equinoxes. The present observations refer to objects entirely self-luminous which are seen in all parts of the sky where sunlight could not reach them, and appear to be at no greater elevation than the higher clouds.

It is only during short periods that the luminous condition of this haze seems to be of frequent occurrence. Apparently it will be absent for a year or so and then for a short time there will be a great amount of it. In 1911 there were frequent displays of it during the spring, summer and autumn, but from 1911, September 22, until 1915, July 2, I have no record of it, though a lookout was always kept for it. It was frequent in the summer and fall of 1910 and also in the spring of 1911. Its prevalence seems to be independent of any auroral conditions. There are a few records of aurora when the haze was present, but only one case in which a large auroral disturbance seems to have been nearly coincident with it. One is impressed with the idea that it is not necessarily an auroral phenomenon and that an appearance of it during an aurora is perhaps purely accidental. Whether this luminous appearance of what is undoubtedly haze, is due to electric conditions or to phosphorescence of some kind does not seem clear.

Sometimes it appears in rather narrow strips several degrees wide and many degrees long; sometimes the form is that of broad sheets covering a large part of the sky. Often both these forms are present at the same time. On one or two occasions I have taken it for the zodiacal light in the east until its motion revealed its true nature. When seen at the eastern horizon it has at times produced the effect of dawn. It is frequently brighter than the Milky Way. From

this it appears that the phenomenon is really conspicuous when seen under good conditions. It seems to have no preference for any special part of the sky. The motion is always easterly. The density of this haze is not great enough to hide the brighter stars over which it passes. In fact, it does not differ from ordinary haze except in being self-luminous. There does not seem to be any fluctuation or pulsation in its light. Under proper conditions it is visible at all hours of the night and in all parts of the sky. Sometimes it is very faint and has to be looked for; at other times it is conspicuous. Often the sky is very pure and dark between sheets or strips of it. It continues luminous as long as it is under observation, which may be for a considerable part of an hour. It is possible that the luminous nights mentioned, where no streaky haze was seen, were due to a thin uniform sheeting of the luminous haze all over the sky.

To make this paper more complete I have written to Dr. W. J. Humphreys for information as to the name and nature of this haze shown on one of my day photographs. He has kindly supplied me with the following:

The streaky haze to which you refer is the cirro-stratus cloud. Near the edge, where it is thin, it might better be called cirrus.

There is no sharp division between cirrus and cirro-stratus. The thin fibrous cirrus often gradually thickens into a more or less continuous cloud veil, or sheet, in which form it is called cirro-stratus.

Its average altitude in middle latitudes is 8 to 10 kilometers. In higher latitudes its altitude is less, say 6 to 8 kilometers; and in equatorial regions roughly 10 to 12 kilometers.

It nearly if not quite always consists of snow crystals, as might be inferred from its altitude and consequent low temperatures, and as is known from the halos often seen in it.

I am also indebted to Professor Eric R. Miller, of the Weather Bureau at Madison, Wisconsin, for valuable data on the frequency of cirrus cloud in Wisconsin. Professor Miller says:

You will learn from the data sent you that there is no part of the year when cirro-stratus is absent; that it is fairly evenly distributed throughout the year.

This information is important as it shows that if the cirro-stratus were naturally self-luminous we should have luminous haze

more frequently at night. If there is no error in my identification of this form of cloud with the luminous haze, it would seem that the material must be frequently present, but that the cause of its luminosity is much less frequent.



FIG. 1. Photograph (August 19, 1917) believed to show the day appearance of the luminous night haze.

The accompanying photograph shows the streaky haze (forming the background for the cumulus clouds) to which Dr. Humphreys refers in his letter and which the present writer believes to be of a similar nature to the haze that sometimes is luminous at night. That shown in the photograph would doubtless be so dense as to blot out the stars at night. Unless, therefore, the haze were much thinner at night it could not be the same. I have seen in the day time a thin gauzy streaky haze, sometimes in large sheets, at the time that the regular denser cirro-stratus clouds were present. These would more readily represent what I refer to as luminous night haze. This I infer is still some form of the cirrus cloud. It

is very important that no mistake be made in the identification and I therefore would call attention to the objection to the denser form of cirro-stratus. This photograph, therefore, represents a denser condition of that cloud and would probably obliterate the stars at night.

In the previous paper (mentioned before) there is a suggestion that the probable passage of the earth through the tail of Halley's comet had something to do with the luminous condition of this haze, because it made its appearance very soon after that event. With the later information there is now no need to call upon the comet for an explanation of the phenomenon.

Following is given a continuation of my records of luminous haze. The times are Central Standard Time, which is 6^h 0^m slow of Greenwich mean time.

1911, June 17. Traces of it were suspected before moonrise, but not certain.

Aug. 28, 10^h 15^m. Masses of it were extending over the bowl of the Great Dipper. They were irregular and very extended to the right and left of the Dipper. The motion was slow, to the right horizontally. At 10^h 35^m it extended the full length of the Dipper and 15° to the right and 10° to the left of it; visible for some time and feebly luminous; steady in its light. At 14^h 35^m there was a long, rather bright luminous strip 4° wide extending along the bowl and handle of the Dipper; horizontal and quite bright. This was perhaps auroral. A few minutes later it had gone. No other signs of aurora.

Sept. 15, 9^h 15^m. Bright auroral streamers from below the horizon, but no arch. In various parts of the sky there were broad streaks and areas of luminous haze. Several very long, broad strips through the Dipper extending east and west. At 9^h 25^m there were thin sheets of it all over the sky, one passing over Brooks' comet which I was photographing, and another one parallel to the first 5° north of it. They extended east and west and were drifting northerly. At 9^h 55^m there were great streams and areas of it with dark spaces between. There was a little auroral light low in the north. At 10^h 10^m the two long masses of haze had drifted north. There were masses of it all over the sky, specially to the south.

Possibly there was also a slight auroral light, but it was mostly luminous haze. This was the most striking display of luminous haze I have seen. In the intervening spaces the sky was pure and dark. The aurora seemed dead at moonrise, when I stopped the exposure on the comet.

Sept. 16, 8^h 30^m. The sky in the southeast was luminous nearly as high as Gamma Pegasi, like approaching moon rise. There was no streakiness in the sky, but I think there was uniform luminosity. The sky was not like that of the night before. No aurora at any time.

Sept. 22, 10^h 0^m. There were great broad and extended masses of luminous haze over the northwest with clear, dark spaces between. Great areas of it were also present south of the zenith. No aurora.

1915, July 2. No aurora, but the night was uniformly luminous.

July 12, 11^h 30^m. No aurora. Luminous haze for 10° below Polaris to Gamma Ursæ Majoris. A feeble sheeting of it extended to the north horizon; its upper edge was quite definite. Above it the sky was dark. No aurora. This haze seemed to be confined to the region described. The other parts of the sky were free from it. At 11^h 50^m the luminous haze had drifted to the right and toward the horizon. It was then horizontal and about 20° below Polaris. Above it the sky was dark, while below it was as bright as the Milky Way to the right of it. At 12^h 25^m there seemed to be more of this, especially to the left of and below Jupiter. There was no aurora. The sky was not very pure. 13^h 0^m: In the east, all about the stars in Aries was a large luminous region almost as bright as the Milky Way; very large, like a great diffused cloud. There were no fluctuations in its light. At 13^h 30^m this haze was about, above and to the right of the Pleiades. It was as bright as the Milky Way. It was large and almost like dimly luminous clouds. There seemed to be a considerable amount of it near the Great Dipper and to the right of the dipper under the pole.

1916, Feb. 2, 14^h 20^m. No aurora, but the sky very luminous—a luminous night. The brightness increased near the horizon.

Aug. 6, 13^h 30^m. There was a region of luminous haze under the pole which seemed to be densest 5° above and 5° to the right

of Alpha Ursæ Majoris. There did not seem to be any evidence of ordinary aurora, but this must have been auroral. It looked as if a feeble moonlight were shining on large hazy clouds.

Dec. 4, 15^h 50^m. Horizontal strips of luminous haze parallel with the horizon under Cassiopeia in the northwest. Sky whitish everywhere, but no definite aurora. 16^h 10^m: Like dim dawn all under Cassiopeia. It consisted of sheets and strips of thin haze, like hazy clouds illuminated by a quarter moon—very noticeable. This was drifting toward the northeast. At 16^h 57^m the upper definite edge of this haze passed just below the Pleiades. It was 5° below and extended 20° to the right of Cassiopeia to under the Hyades. At 17^h 10^m it was nearing the northwest horizon. This was the best specimen of luminous haze in many years.

Dec. 21, 8^h 40^m. There seemed to be a long horizontal strip of luminous haze 3°–4° wide passing through Zeta Ursæ Majoris. No regular aurora. 9^h 25^m: A considerable amount of broad luminous haze west of the previous strip.

1917, Aug. 10, 9^h 18^m. Large faint auroral streamers from the north horizon. 9^h 34^m: Several slender auroral streamers. 10^h 50^m: Large areas of luminous haze in the east and near Beta Ursæ Minoris. 10^h 57^m: From the east horizon up to Alpha Arietis was a great sheet of faintly luminous haze slanting upward at the south end. A large area of luminous haze through Beta Ursæ Minoris to the north horizon, several degrees wide. Feeble luminous haze in high east sky. There were dark areas of pure sky free from luminous haze. Another feeble luminosity in the low north. There were no auroral streamers. By 11^h 20^m the luminous haze had drifted to the east of Polaris. Large areas of it all over the sky. It could be seen though the moon was up. (Moon last quarter August 9.) This luminous condition was not due to moonlight. It was the regular luminous haze seen in previous years.

Aug. 15, 8^h 50^m. Some masses of luminous haze. A great V-shaped portion with one broad leg through the Square of Pegasus, and the other 10° south of Altair. They met near the horizon south of the square of Pegasus. These were perhaps "left overs" from the previous night's aurora, but there was no trace of aurora to-night. At 9^h 55^m the great stream of luminous haze lay

between Cassiopeia and Perseus, and was 10° under Polaris. It was 10° broad. Another ran through Alpha Cassiopeia and met the first near the southwest horizon. There were several streams of it from the intersection running upwards. These were as bright as the Milky Way near Alpha Cygni. The sky between was very clear. At $11^h 10^m$ the luminous band in the northeast was between Alpha Persei and Capella. It was bright—brighter than any part of the Milky Way. There were many less bright strips to the east of the zenith. No aurora. (On August 14 there was a large aurora.) $12^h 45^m$: All the sky except overhead was unequally covered with luminous haze. In the east and northeast there were great long streaks of it, 10° or more wide. Also in the south. This was as bright as the Milky Way. It was very strikingly dark where the sky showed between.

Aug. 16, $10^h 0^m$. A very feeble glow low in the north, like a very faint aurora. No luminous haze to-night so far. At $10^h 20^m$ there was a broad strip of luminous haze running from Altair east by north through a point in $\alpha 22^h 20^m$, 8° . It was 10° broad and quite noticeable when looked at for a few minutes. $11^h 40^m$: Strong aurora with streamers and very low arch. $12^h 20^m$: Aurora not very active, but strong glow. At $12^h 50^m$ there was only a strong auroral glow.

Aug. 18, $10^h 55^m$. No aurora, but sky luminous; perhaps some luminous haze in the south. $15^h 52^m$: East edge of a broad sheet of luminous haze passing over Alpha Arietis. $15^h 58^m$: The south edge of this was passing the Pleiades. $16^h 2^m$: East edge over Jupiter. $16^h 23^m$: It was now massing up into little patchy clouds. There was a great amount of it all over the sky. It was pale white. There were some dark clouds lower in the east against the dawn.

Aug. 19, $10^h 15^m$ to $10^h 45^m$. Looked carefully for luminous haze, but none was visible. Sky very thickish; Milky Way very dull. $15^h 15^m$: Sky very dull. No luminous haze or clouds. $15^h 33^m$: No luminous haze. Sky thickish; specially thick over Jupiter and the Pleiades. Some misty haze—not luminous. Some zodiacal light at $15^h 42^m$. Some feeble luminous haze above Jupiter and the Pleiades. A great deal of dark haze; a long mass of it was probably feebly luminous in Cassiopeia and evidences of it at a

number of other places. 15^h 50^m: There were streaks and masses of haze feebly luminous near the Pleiades; some strong strips and great sheets of it all over the south. These were not self-luminous, but were all brought into view, evidently, by reflecting the first feeble dawn. They were, however, beyond question the same stuff that had recently appeared luminous at night.

Aug. 24, 12^h 50^m. No aurora. There were horizontal strips of luminous haze through the upper part of the Great Dipper with a clear space below them, with more luminous haze lower down. Great long masses through Hercules with clear space below; then more of it to the northwest horizon. 14^h 30^m: A rather strong strip of luminous haze just above the handle of the Great Dipper in the north. There was also a horizontal strip across Vega with a clear space below it. No aurora. The sky where there was no luminous haze was very clear. 15^h 50^m: No aurora.

Dec. 21, 14^h 10^m. No aurora. 14^h 44^m: No aurora. I noticed a little later what appeared to be a strong zodiacal light passing through Spica in the southeast at 14^h 57^m; this proved to be an extended luminous haze. At 15^h 30^m the upper part of it passed through Alpha and Epsilon and Beta Crateris and Gamma Hydræ. The upper edge was rather definite. The whole mass extended from the east horizon to beyond Crater. The motion of all this was to the southeast. The sky was dark below Spica to the edge of the haze. There was much very diffused light extending above Spica for 20° or more. 16^h 25^m: A diffused luminosity like dawn all along the southeast horizon and upwards where the luminous haze had drifted, no aurora. 17^h 5^m: There was a dawn-like light all about Alpha and Beta Libræ. 17^h 30^m: No aurora. The zodiacal light was very strong. No luminous haze anywhere. This exhibition of luminous haze was very noticeable. At first it was taken for the zodiacal light and thought to be unusually bright, but it drifted to the southeast and disappeared before the zodiacal light manifested itself. The light of the luminous haze was soft, like that of the zodiacal light, but stronger, and there was a rather definite edge to it. There was no evidence of aurora at any time, though looked for carefully. There was no other luminous haze. This was extended from the east horizon to above Spica at first, to the southeast, almost horizontally, beyond Alpha Crateris.

1918, Sept. 2, 9^h 17^m. A strip of luminous haze 4° wide ran diagonally across the Square of Pegasus from Beta and beyond Gamma Pegasi. 9^h 24^m: A similar mass ran from the Dolphin to Alpha Pegasi. No aurora. 10^h 35^m: No aurora. A region of luminous haze over the handle of the Dipper in the northwest. There seems to have been a great deal of it on this night. 11^h 25^m: Luminous haze all over the north; a great sheet of it with clear spaces here and there. No aurora on this night, but a great deal of luminous haze.

Sept. 8, 9^h 30^m. At this time there was a great deal of luminous haze all over the northwest, as high as 4° or 5° above the Dipper. It was quite strong. A long strip of it 5° wide extended from above Gamma Pegasi to Aries. Though there was no aurora on this night, there was a great deal of luminous haze.

Oct. 5, 12^h 30^m. The sky was luminous. There was no aurora. It was about as bright as if a quarter moon were, say, in the west. It was uniform and was apparently not the regular light of luminous haze. Could readily read my watch by this light. The Milky Way was very dim with it.

I have gone to some length in the descriptions and locations of the masses, etc., of luminous haze because so little is known of the origin of its light that it is believed the observations may sometime be more important than they appear to be at present.

The following tabular scheme will roughly show the frequency of luminous haze as indicated by my records. The numbers indicate the number of nights on which it was seen during the month.

	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.	1918.
January.....		..	..	..	..	..	..	..	..
February.....		I	..	..	..	..	I	..	..
March.....		I	..	..	..	..	..	..	..
April.....		..	..	..	..	..	..	..	..
May.....		..	..	..	..	..	..	..	..
June.....	3	I	..	..	..	..	..	..	..
July.....	..	..	..	..	..	2	..	..	..
August.....	..	I	..	..	..	..	I	6	..
September.....	2	3	..	..	..	..	..	..	2
October.....	5	..	..	..	..	..	..	..	I
November.....	2	..	..	..	..	..	..	..	..
December.....	..	..	..	..	..	..	2	I	..

As will be seen from the above table, January, April and May

seem to be the only months in which the haze was not observed. It was not seen during the years 1912, 1913 and 1914. The greatest amount of it was recorded in October, 1910, and August, 1917. The first half of 1910 must not be considered because the haze was not noticed until June and as it was not looked for it may have been present.

A strict comparison cannot be safely made between the frequency of luminous haze and that of the aurora by noting the relative number of nights on which they were visible, because often auroras appear in the presence of bright moonlight in which the luminous haze would not be visible. Nevertheless, it may be important to have even a rough comparison. For this purpose, therefore, I have collected the following dates on which auroras were seen, which covers the entire period over which the luminous haze has been under observation by me. They are from my own records of the aurora which I have kept here for over twenty years. The dates alone are given. A [?] means uncertainty as to whether the observation was of a real aurora. Some of the auroras are of very short duration and hence the apparition of an aurora on the date of an observation of luminous haze may not have been coincident with the latter by many hours. The details of the above auroral records will be published later as a continuation of the two lists already printed in the *Astrophysical Journal*, Vol. 16, p. 135, 1902 and Vol. 31, p. 208, 1910.

1910, May	3	Oct.	2[?]	Mar.	20[?]
"	18	"	7	"	24
"	24	"	27	"	30
"	27	"	30	Apr.	8
"	30	Nov.	1	"	16
June	19	"	29	May	31
July	4	1911, Feb.	20	June	4
Aug.	9	"	21	July	17
"	10	"	22	Aug.	2
Sept.	6	"	23[?]	"	22
"	10	"	24	"	23
"	27	"	28	"	24
"	30	Mar..	19	"	28

Sept.	15	July	1	Aug.	22
"	19	"	5	"	23
"	21	"	8	"	26
Oct.	10	"	11	"	27[?]
1912, Jan.	12	Aug.	6	"	28
May	13	"	17	Sept.	2
June	7	"	19	"	4
"	8	Sept.	9[?]	"	7
Nov.	14	"	16	"	16
"	15	"	21	"	22
1913, Feb.	13	"	28	"	30
Mar.	13	"	29	Oct.	1
Aug.	29[?]	Oct.	1[?]	"	5
Sept.	22	"	14	"	6
1914, Apr.	18	Nov.	1	"	7
July	24	"	5	Nov.	20
"	29	"	8	Dec.	27
Aug.	28	"	11	"	28
Sept.	15	"	16	1917, Jan.	7
"	17	Dec.	7	"	25[?]
"	22	1916, Jan.	10	Feb.	17
"	25[?]	"	22	"	19
"	28	Mar.	8	"	27
Oct.	20	"	10	Mar.	19[?]
"	27	"	16	"	20
Nov.	15	"	29	May	1
"	16	Apr.	1	"	2
1915, Apr.	2[?]	"	5	June	13
"	7	"	27	July	1
"	16	May	22	"	12
"	17	"	30	"	28
"	25	June	19	Aug.	8
May	16	"	24	"	9
June	16	July	5	"	10
"	17	"	8	"	14
"	21	"	23	"	16
"	24	Aug.	19	"	25

Oct.	13	Apr.	17	Oct.	3
"	24	"	29	"	6
"	27	July	30	"	8
Nov.	18	Aug.	2	"	9
Dec.	8	"	5	"	15
"	14	"	24	"	16
1918, Jan.	13	"	25	Nov.	10
Feb.	12	"	26	"	11
Mar.	3	"	28[?]	"	12
"	7	"	31	"	13
"	14	Sept.	7	"	24
"	15	"	12	"	29
Apr.	3	"	15	"	30
"	4	"	26	Dec.	3
"	5	"	28	"	7
"	6	"	29	"	8
"	8	"	30	"	19[?]
"	10	Oct.	2[?] 1919, Jan.		3

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 April 4, 1919.